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CLAIMS

1.   A method of measuring twist in a rotating shaft which is subjected to torque, between a datum point on the shaft and a measure point on the shaft longitudinally spaced from the datum point, the method including

5   establishing a datum time period between a datum time moment the datum point passes a stationary datum station and a time moment the measure p int passes a stationary measure station under a no load condition and recording rotational speed of the shaft as the datum speed;

measuring a measure time period between a time moment the datum point

10   passes the stationary datum station and a time moment the measure point passes the stationary measure station when the shaft is subjected to torque, recording the rotational speed of the shaft as the measure speed and establishing a length of the shaft over which torque is applied;

calculating the twist in the shaft on the basis of the difference between the

15   measure time period and the datum time period, the measure speed and the length over which torque is applied.

2.   A method as claimed in Claim 1 in which a torque point at which torque is applied to the shaft and a load point at which a load is connected to the shaft are longitudinally spaced, the shaft being stressed and undergoing twist

20   between the torque point and the load point, one of the measure point and th datum point being positioned along said stressed portion of the shaft, the other of the measure point and the datum point being positioned in a relaxed portion of the shaft beyond one of the torque point and the load point.

3.   A method as claimed in Claim 2 in which the shaft is a crankshaft of

25   a reciprocating internal combustion engine.

4.   A method as claimed in Claim 3 in which the reciprocating engine includes a ring gear having gear teeth at one end of the crankshaft and a disc at an opposed end of the crankshaft, the datum point b ing on the disc, the measure point being on a gear tooth of the ring gear.

30   5.   A method as claimed in Claim 4 which is performed in respect of a

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plurality of measur points and a plurality of datum points, the plurality of m asure points being on a corresponding plurality of gear teeth of the ring gear and the plurality of datum points being points which are circumferentially spaced on the disc.

5 6. A method as claimed in Claim 5 in which the reciprocating internal combustion engine includes a plurality of cylinders, the method being performed in respect of each cylinder.

7. A method as claimed in Claim 5 or Claim 6 which is performed for each power stroke of the reciprocating internal combustion engine.

10 8. A method as claimed in Claim 2 in which the shaft is a main shaft of a gas turbine engine.

9. A method as claimed in Claim 8 in which at least one of the datum point and the measure point is on a vane of at least one of a compressor and a turbine of the gas turbine engine.

15 10. A method as claimed in Claim 9 which is preformed in respect of a plurality of measure points and a plurality of datum points, the plurality of measure points being on a corresponding plurality of vanes of one of the compressor and the turbine and the plurality of datum points being on a corresponding plurality f vanes of the other of the compressor and the turbine, the sensors being external 20 of casings surrounding respectively the compressor and the turbine.

11. A method as claimed in any one of Claim 1 to Claim 10 inclusive in which establishing the time moments includes triggering a sensor at respectively the datum station and the measure station by means of triggers at correspondingly the or each datum point and the or each measure point, creating a signal by each 25 sensor and recording the signal against time.

12. A method as claimed in Claim 11 in which the triggers are masses of magnetic material, and the sensors are responsive to said magnetic material to cr ate said signals.

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13.   A method as claimed in Claim 11 in which th triggers are optically detectable surfaces, and the sensors sense passing of the triggers optically.

14.   A method of measuring twist in a rotating shaft which is subjected to torque including sensing and recording a datum time moment when a datum
5   point on the shaft passes a fixed datum station; sensing, at a fixed measure station, an arrival time moment of a measure point on the shaft, longitudinally spaced from said datum point by a predetermined distance; measuring a measure time period between said datum time moment and said arrival time moment; measuring rotational speed of the shaft; comparing the measure time period with
10   a computed time period under a no load condition; and calculating the twist in the shaft on the basis of the time lag and the rotational speed.

15.   A method as claimed in Claim 14 which includes empirically predetermining a datum time period between a datum time moment and an arrival time moment under a no load condition at a determined rational speed, and
15   computing a computed time period and a computed arrival moment for any specific rotational speed on the basis of the datum time period bearing in mind the respective rotational speeds.

16.   A measuring apparatus for measuring twist in a rotating shaft which is subjected to torque, the measuring apparatus including
20   at least one datum trigger at a datum point on the shaft;
          a datum sensor at a stationary datum station arranged to sense said at least one datum trigger when said at least one datum point is in register with the datum station and to generate correspondingly at least one datum signal;
          at least one measure trigger at correspondingly at least one measure point
25   on the shaft longitudinally spaced from said at least one datum point;
          a measure sensor at a stationary measure station arranged to sense said at least one measure trigger when said at least one measure trigger is in register with the measure station and to generate correspondingly at least one measure signal;
          a clock keeping time;
30   a rotational speed meter for measuring and recording rotational speeds of the shaft against time respectively as the datum speed and as the measure speed;
          recording means for recording said datum and measure signals against time;

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a processor programmed to establish

correspondingly at least one datum time period between a time moment said at least one datum point passes the datum station and a time moment said at least one measure point passes the measure station under n load
5   conditions and recording the rotational speed of the shaft as the datum speed,

correspondingly at least one measure time period between a time moment said at least one datum point passes the stationary datum station and a time moment said at least one measure point passes the stationary measure station when the shaft is subjected to torque and recording the rotational speed of the
10   shaft as the measure speed, and

the twist in the shaft on the basis of the difference between said at least one measure time period and said at least one datum time period, the measure speed and a length of the shaft over which torque is applied.

17.   A measuring apparatus as claimed in Claim 16 in which the shaft
15   includes a torque point at which torque is applied to the shaft in use and a load point at which a load is connected to the shaft in use, the torque point and the load point being longitudinally spaced, the shaft, in use, being stressed and undergoing twist between the torque point and the load point, one of the or each measure point and the or each datum point being positioned along said stressed
20   portion of the shaft, the other of the or each measure point and the or each datum point being positioned in a relaxed portion of the shaft beyond one of the torque point and the load point.

18.   A measuring apparatus as claimed in Claim 17 in which the shaft is a crankshaft of a reciprocating internal combustion engine.

25   19.   A measuring apparatus as claimed in Claim 18 which includes a plurality of measure points and a plurality of datum points.

20.   A measuring apparatus as claimed in Claim 19 in which the reciprocating engine includes a ring gear having gear teeth at one end of the crankshaft and a disc at an opposed end of the crankshaft, the datum points and
30   the measuring points being respectively on gear teeth of the ring gear and at circumferentially spaced positions on the disc.

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21.   A measuring apparatus as claimed in Claim 17 in which the shaft is
a main shaft of a gas turbine engine.

22.   A measuring apparatus as claimed in Claim 21 in which at least one
of the datum point and the measure point is on correspondingly at least one of a
5   vane of a compressor and a vane of a turbine of the gas turbine engine.

23.   A measuring apparatus as claimed in Claim 22 which includes a
plurality of datum points and a plurality of measure points, the datum points and
the measure points being respectively on vanes of the compressor and the turbine.

24.   A measuring apparatus as claimed in any one of Claim 16 to Claim
10   23 inclusive in which the triggers are masses of magnetic material, and the sensors
are responsive to said magnetic material to generate signals.

25.   A measuring apparatus as claimed in Claim 24 in which the sensors
are in the form of magnetic sensors arranged external of casings surrounding
respectively the compressor and the turbine.

15   26.   A measuring apparatus as claimed in any one of Claim 16 to Claim
23 inclusive in which the triggers are optically detectable surfaces, and the sensors
are optical sensors responsive to the optically detectable triggers to generate
signals.

27.   A method of measuring torque in a rotating shaft, including
20   measuring twist in the rotating shaft in accordance with any one of Claim 1 to
Claim 13 inclusive, and calculating torque on the basis of the measured twist
bearing in mind a pre-established length of the shaft over which length said twist
is measured, and pre-established physical characteristics of the shaft determining
torque-twist behaviour of the shaft.

25   28.   A method as claimed in Claim 27 in which said physical
characteristics of the shaft determining torque-twist behaviour of the shaft are
established empirically.

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29.   A measuring apparatus for measuring torque in a rotating shaft, which includes a measuring apparatus for measuring twist as claimed in any on of Claim 16 to Claim 26 inclusive, in which the processor is programmed to calculate torque on the basis of the measured twist bearing in mind a pre-

5   established length of the shaft over which length said twist is measured and pre-established physical characteristics of the shaft determining torque-twist behaviour of the shaft.

30.   A method of managing operation of an engine including measuring a quantity related to torque in a drive shaft of the engine as claimed in any one of

10   Claim 1 to Claim 13 or Claim 27 or Claim 28, comparing the measured value of said quantity related to torque to a predetermined standard value of said quantity, establishing any deviation between the measured value and the standard value and controlling an operating function of the engine in response to said establish deviation.

15   31.   A method as claimed in Claim 30 in which said operating function of the engine is at least one of ignition timing when the engine is a spark ignition engine, injector pump timing when said engine is a diesel engine, boost pressure when said engine is turbocharged or supercharged.

32.   A method as claimed in Claim 30 or Claim 31 including automatically

20   calibrating the measuring apparatus in respect of datum time periods when the engine is operated under a no load condition.

33.   An engine including

        a measuring apparatus as claimed in any one of Claim 16 to Claim 26 or claim 29;

25   an engine management apparatus including a comparator arranged to receive a signal indicative of a measured value of a quantity related to torque in a drive shaft of the engine from the measuring apparatus, the comparator being preprogrammed to compare said measured value with a standard value of said quantity related to torque to generate a control signal, the engine management

30   apparatus being responsive to said control signal to control an operating function of the engine.

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34.   An engine as claimed in Claim 33 in which said operating function of the engine is at least one of ignition timing when the engine is a spark ignition engine, injector pump timing when said engine is a diesel engine, boost pressure when said engine is turbocharged or supercharged.

5 .35.   An engine as claimed in Claim 33 or Claim 34 in which the engine management apparatus is preprogrammed to calibrate the measuring apparatus in respect of datum time periods when the engine is operated under a no load condition.